Institution: Kingston University

Unit of Assessment: 15, General Engineering

Title of case study: Industrial take-up of advanced manufacturing process for nanomaterials

1. Summary of the impact (indicative maximum 100 words)

Research at Kingston University into the use of flame spray pyrolysis (FSP) to manufacture metal oxide nanoparticles has resulted in the creation of an industrial FSP nanoparticle production line. This achieves production rates an order of magnitude higher than was previously achievable, while allowing particle size to be controlled at the same scale as existing small FSP processes.

TECNAN, a Spanish SME, established in 2007, that manufactures and sells nanomaterials on the international market, has used this production line to produce a range of nanoparticles for commercial customers, for use in a wide range of applications. As well as allowing a broad product range to be offered, the production line also achieves a cost reduction of over 30% compared to previous manufacturing methods.

2. Underpinning research (indicative maximum 500 words)

In the flame spray pyrolysis (FSP) process, nanoparticles are produced from a liquid precursor into solid particles in less than 10^{-3} seconds. In such a short time, multi-component atomisation, evaporation and combustion of precursor solutions as well as nanoparticle growth take place from the starting materials of the liquid precursor and solvent. The size and properties of the final products are strongly influenced by the profile of the flame, which is a function of the geometry of the reactor and the processing parameters. The length of the flame will increase when the production rate is increased, which leads to a large particle size. As a consequence, desirable nanoparticles may not be produced. The challenge is to control the particle size in large scale production. This requires a good understanding of the effects of reactor geometries, production rates and processing parameters. Experimental work is time consuming, expensive and unable to provide sufficient information about the change from liquid precursor to solid particles. Computer simulation is necessary for the development of an industrial scale production line.

The work at Kingston University (KU) was based on previous research experience in thermal spray technology. The key component for the FSP production equipment is the reactor, which in principle is similar to the gun used in thermal spray. The Materials and Composites Research Centre (MCRC) at Kingston has been working on thermal spray for over 10 years. Software developed in-house as well as commercial software (Star-CD and Ansys) were used to simulate combustion, the temperature/velocity profile of the flame and the interaction between the flame and particles within it. These techniques were further developed in the FSP project to investigate the effects of geometry, properties of precursors and processing parameters. In the FSP process, the nanoparticles are synthesized from precursors in the flame. This is related to the research work on combustion synthesis carried out in the MCRC. The measurement technique (high temperature and viscosity) and thermal dynamics for synthesis together with the materials characterisation were directly used in the FSP project.

For this project, the computational models developed at KU modelled both the atomisation of precursors and dynamics of particle growth. These models were coupled with Ansys-Fluent to predict the formation of droplets, droplet transport, heat and mass transfer and combustion in flames, formation of nanoparticles, particle growth and agglomeration. These models were validated by comparing with experimental values measured by industrial partners (L'Urederra, Spain; ETH, Switzerland; Johnson Matthey Plc (JM), UK.). The effect of pressure drop, sheath gas flow rates and position, gas to liquid flow ratio, production rate and precursor concentration were studied at KU. The computational models were able to provide the necessary information for the design of the industrial scale FSP reactor. The research has led to an improved understanding on the behaviour of materials during processing and the development of new manufacturing processes.

Key Researcher: Professor Tao Zhang (Kingston University, January 2002 to present).

3. References to the research (indicative maximum of six references)

Research publications related to this research

1. H. Torabmostaedi, T. Zhang, P. Foot and S. Dembele1, C. Fernandez, "Process control for the synthesis of ZrO2 nanoparticles using FSP at high production rate", Powder Technology, 246 (2013) 419–433.
2. Gao, J., Zhang, T., Bao, Y. and Gawne, D.T. "Plasma-scan sintering of aluminosilicate sol-gel films", Journal of the European Ceramic Society, 30(4) (2010) pp. 847-855.
3. X. Zhu, T. Zhang, D. Marchant and V. Morris, "The structure and properties of NiAl formed by SHS using induction heating", Materials Science and Engineering A 528 (2011) 1251–1260
4. X. Zhu, T. Zhang, D. Marchant and V. Morris, "Combustion synthesis of TiC–NiAl composite by induction heating". Journal of the European Ceramic Society 30 (2010) 2781–2790.
5. X. Zhu, T. Zhang, V. Morris and D. Marchant, "Combustion synthesis of $NiAl/Al_2O_3$ composites by induction heating", Intermetallics 18 (2010) 1197-1204.
6. T. Zhang, B. Liu, Y. Bao and D.T. Gawne, "Statistical analysis of the motion and heating of particles in a plasma jet", Plasma Chemistry and Plasma Processing, 25 [4] (2005) 403-425.

Grants

EU FP7 "Large scale production of tailored nano-oxides by advanced, high-output, high-versatility flame spray pyrolysis Advance-FSP", Grant agreement nº: CP-FP 228885-2 ADVANCE-FSP
Total EC contribution: €3,080,926, of which KU receives €197,590.
PI: T. Zhang in KU.
Start date: 1/11/09, duration 48 months.

Report:

Large scale production of tailored nano-oxides by advanced, high-output, high-versatility flame spray pyrolysis. Deliveverable report produced by KU. [Available on request]

4. Details of the impact (indicative maximum 750 words)

Based on this research, a prototype industrial FSP nanoparticle production line has been produced, which achieves continuous and reliable production at a rate of 2 - 5 kg/hour, depending on the materials. This is an order of magnitude higher than was previously achievable. The size of particles can be controlled at a scale of 15 nm, which is similar to the scale obtained in the small FSP laboratory reactors that are currently in use. Thus, nanoparticles can be produced on an industrial scale with similar quality to that achieved in the laboratory.

This nanoparticle production line is now in commercial use by TECNAN, a Spanish SME established in 2007 that manufactures and sells nanomaterials on the international market.

The company manufactures and sells a wide range of nanomaterials produced with this production line, including a range of simple nano-oxides with small particle diameter and high purity, and a smaller number of complex nano-oxides, and a wide variety of mixed or complex custom-made nanoparticles to meet clients' specifications.

The technology also allows TECNAN to produce a wide range of specialized complex nanoparticles with the same ease and effectiveness as simple nanoparticles. Thus TECNAN offers products such as mixed nano-oxides of various elements, nano-oxides doped with different metals and even complex "core-shell" structures, custom-made on demand to meet clients' specifications.

These products have been used in a range of applications, including catalysts for chemical processes, photoactive materials for the manufacture of solar cells, ceramic materials as hardening agents for enamel used in orthopaedic implants, dental prosthesis, and cosmetic and pharmaceutical products.

As well as enabling this product range to be offered, the production line also improves industrial competitiveness. The particle size can be controlled at less than 15 nm, at a cost much lower than commercial products produced with previous methods (a cost reduction of over 30%).

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Testimonial from Chairman of the Board, TECNAN: corroborates all aspects of impact.